GOULD ISLAND BUILDING DEMOLITION STRUCTURAL REVIEW REPORT - ADDENDUM NO. 1

GOULD ISLAND
NAVAL STATION NEWPORT
MIDDLETOWN, RHODE ISLAND

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Prepared for:

NORTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
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1.0 INTRODUCTION

Foster Wheeler Environmental Corporation (Foster Wheeler) was contracted by the Northern Division Naval Facilities Engineering Command to provide Demolition of Selected Buildings on Gould Island located in Newport, Rhode Island. As part of the contract, Foster Wheeler prepared a work plan for the project entitled, "Work Plan for Gould Island Demolition of Selected Buildings - Phases I, II, & III" (the "Work Plan"). This addendum has been prepared to focus on the demolition of Building No. 35 based on information provided by the Navy. An overview of the project is provided below.

1.1 Project Overview

Gould Island is located in Narraganset Bay approximately 1.5 miles from Naval Station, Newport. As described in the Work Plan, Foster Wheeler will perform asbestos abatement (Section 4.3 of the Work Plan), hazardous waste removal activities (Section 4.4 of the Work Plan), demolition of designated buildings (Section 4.5 of the Work Plan), and removal of all associated building slabs and foundations (Section 5.0 of the Work Plan) on Gould Island. Foster Wheeler will perform this work in three phases.

Phases I and II include asbestos abatement, hazardous waste removals, and demolition of the buildings to the slab elevation only. Phase III activities include the removal and crushing of all associated building slabs and foundations.

In support of the building demolition, Foster Wheeler performed a structural review of the buildings to ensure a proper sequencing for the demolition process. A description of the process and recommendations for the demolition are provided below.

1.2 Structural Review Description

As stated in Section 4.5 of the Work Plan, prior to demolition, Foster Wheeler will utilize a licensed structural engineer to review and approve the building demolition process. The structural review focused on the demolition of the three largest buildings at the Site. These buildings included Building No. 32, Torpedo Overhaul Shop; Building No. 33, Power Plant; and Building No. 35, Test Facility (Brick Portion) as shown on Figure 2-2 of the Work Plan. Demolition of Buildings No. 32 and 33 were recently completed at the site. Building No. 35 is the final building to be demolished. Foster Wheeler has begun specific demolition activities in Building 35 and the final demolition of the building will conclude in April of 2001. This addendum to the structural review focuses on the demolition of Building No. 35.

2.0 BUILDING DEMOLITION

2.1 Test Facility (Brick Portion) - Building 35

2.1.1 Building Description

Building 35 is located at the northern most end of Gould Island. The building is built on a pier supported by square concrete piles[1]. Based on drawings provided by the Navy[2], the building is constructed on a reinforced concrete slab supported by reinforced concrete beams of varying width which are supported by groups of 20-inch square concrete piles. A description of the foundation construction is provided below.

According to the 1993 Underwater Inspection Report, sub-section 3.9.3, "the square reinforced concrete piles are in excellent condition. Except for the two broken piles, they are fully able to perform as they were designed. The reinforced concrete deck which supports Building 35 and is supported by the steel pipe piles and reinforced concrete piles is in good condition with minor cracking on the pile caps and deck. On the west face of the deck structure deterioration of the concrete is accelerated as a result of exposure to the weather and salt spray. Currently this area has not lost significant strength and loading can be maintained at current levels; however, to maintain structural integrity, repairs should be made to stop the intrusion of chlorides into the concrete."

The footprint of the building portion to be removed measures approximately 288ft. long x 42ft. wide. From the southern end of the building, the first 108 ft. long x 42ft. wide section is one-story tall (approximately 18ft. high). The next section of the brick building, extending to the portion to remain, is two-stories high with approximate dimensions of 180ft. long x 42ft. wide x 28ft. high.

2.1.1.1 Building Foundation

The concrete piles supporting the building were installed to bedrock and were installed in groups or as single plumb piles. These piles support the east-west and north-south aligned beams. Along the west side beam, batter piles were installed along the full length of the building. Beginning from the west side of the building, the first north-south aligned reinforced concrete beam (noted as Beam 1 or B1 on drawing no. 4245-49) is 94 inches wide and supported by groupings of plumb piles with center to center spacing of 18 feet. This beam supports the west side building wall and columns. The center beam aligned in a north-south direction (noted as Beam 2 or B2 on drawing no. 4245-49) is 20 inches wide and supported by single piles with center to center spacing of 18 feet. The east side beam aligned in a north-south direction (noted as Beam 4 or B4 on drawing no. 4245-49) is 40 inches wide and supported by groupings of

[1] "Underwater Inspection Report of Waterfront Structures at the Naval Undersea Warfare Center, Newport, RI" dated February 25, 1993

[2] P.W. Drawing No. 4245-49, "Firing Pier, Deck Framing Plan," Revision B, dated March 17, 1942 (Attached as 11x17); P.W. Drawing No. 4334-50, "Firing Pier, Details & Sections," Revision B, dated March 17, 1942 (Attached as 11x17); and P.W. Drawing No. 7491-81, "Firing Pier, Pile Plan," Revision I, dated June 29, 1943 (Not Attached).

plumb piles with center to center spacing of 18 feet. This beam supports the east side wall and columns of the building. These north-south beams have center to center spacing of 20 feet.

The beams aligned in the east-west direction (noted as Beam 9 or B9 and Beam 10 or B10) are all 20 inches wide. These beams have center to center spacing of 18 feet and are supported on the same pile groupings as the north-south beams.

The flooring of the building is a reinforced concrete slab of varying thickness. The concrete slab located between the edge of the pier and the outside building face is 5.5 inches thick and the concrete slab within the interior of the building is 7.5 inches thick. For the interior concrete slab, the north-south span is approximately 18 feet and the east-west span is approximately 20 feet. According to drawing no. 4245-59, the design floor load (live load) equals 125 pounds per square feet.

2.1.1.2 Building Construction

The building is constructed with steel columns with center-to-center spacing of approximately 18ft. in the north-south direction and span the entire width of the building in the east-west direction (approximately 41ft.). These steel columns are encased in concrete/brick and support the primary steel beams on the first and second floor (where applicable), which are also encased in concrete/brick. The primary steel beams on both the first and second floors are spaced 18ft. apart and aligned in an east-west direction. The secondary support beams on both the first and second floors are encased in concrete/brick, spaced approximately 10ft. apart and aligned in a north-south direction. The floor slab on the second floor and the roof slab, approximately 4" to 5" thick, are supported by these primary and secondary beams.

The exterior walls are constructed of brick. The concrete roof slab is covered with several layers of paper/roofing tar and pea stone.

The northern section of the building, which measures approximately 170ft. long x 82ft. wide and height varying from 28ft. (south side) to 47ft. high (north side), is in use and will not be demolished.

2.1.2 Building Demolition Process

The demolition process for this building has been revised based on information provided by historic drawings, a site visit to confirm information on the drawings, and an underwater pile investigation. Due to load restrictions of the concrete slab, the use of a hydraulic excavator on the concrete pier is impractical (see the structural assessment section below). The new demolition approach will be to utilize smaller equipment for the clean up of demolition debris on the pier and to demolish the building with equipment working from barges adjacent to the work area.

The building demolition will be performed in several phases. Phase I will be the separation of the southern building portion to be demolished from the northern building portion to remain.

This phase will also include the removal of interior piping, equipment, miscellaneous debris and interior wooden structures. Phase II will be the demolition of the exterior walls, utilizing a crane, equipped with a 2,000 pound demolition ball, staged on a barge. Phase III of the demolition will include the removal of the remainder of the structure utilizing equipment from a barge (hydraulic excavator and barge-mounted crane) along with low-pressure equipment (bobcat skid steer loader, rubber tire backhoe, all terrain fork truck) on the slab for debris removal. These demolition phases are detailed below.

2.1.2.1 Structural Assessment of the Building

Based on the information provided by the historic drawings along with information gathered during site visits, Foster Wheeler performed calculations to determine the feasibility of the use of a hydraulic excavator (PC 300LC-6, Approximate operating weight 80,000lbs.) on the pier during building demolition in an approach similar to Buildings 32 and 33. The site visit, conducted by Foster Wheeler confirmed some dimensions of the concrete foundation (*i.e.,* slab thickness, beam layout, pile orientation, *etc.*).

Drawing No. 4245-49, 4334-50 and 7491-81 provided dimensions, spacing, reinforcement size/spacing, plan and section views, *etc.* to aid in the review of the structural components. The concrete slab governs the allowable load for equipment to be used on the pier for the demolition. Based on calculations performed, the concrete slab will not be able to support a hydraulic excavator. Foster Wheeler also computed the loading for an excavator working on top of crane mats placed over the west side beam. Even with the load spread over the crane mats, the slab will not be able to support the hydraulic excavator. Therefore, it is recommended that the hydraulic excavator perform demolition activities from a barge. Engineering calculations are provided as an attachment to this document.

2.1.2.2 Phase I - Separation from the Building Section to Remain

The northern portion of Building 35 is currently being utilized by the Navy. This portion of the building will be left intact and requires separation from the portion to be demolished. The attached site map shows the portion to remain and the portion to be demolished. To insure that this building portion is not impacted during the demolition, Foster Wheeler will first remove a section of the building where it joins the portion to remain by dismantling the first 18ft. long by 42ft. wide by two-story high section in its entirety.

The span between the two primary support beams is 18ft. This will create a clean separation from the northern building section to remain and create an open area for falling debris during the demolition of the section to be removed.

The first step in the separation process will be to make vertical saw cuts along the brick wall in front of the steel columns. A crane-working from a barge, will then ball the brick wall inward. The demolished brick wall will be removed from the floor slab manually on the second floor and by utilizing a bobcat skidsteer loader, or similar light equipment, on the first floor. Loose brick will be placed as fill in areas south of Building 35 or moved to the staging area on the landward part of the site.

The second step will be to remove the roof and second story floor in sections. The sections will be measured and calculated for weight to insure a safe load for the barge mounted crane. Each section of slab to be removed will be supported beneath with scaffolding/shoring. The concrete wet saw will cut each section. A lift permit will be issued for a crane to operate from the barge to lift each section of the roof slab. Drilled-in anchor bolts will be embedded into the slab for rigging points. A four-point pick with a four-part cable system will be used for the lift. Each section will be removed and relocated to a designated staging area.

Once the roof and second floor have been removed, the third step will be to chip the concrete encasement away from the areas on the secondary steel beams where they connect to the primary beams to facilitate cutting of the steel beams. The concrete will also be chipped away from the areas on the primary steel beams where they connect to the columns.

Next, the secondary steel beams will be cut (torch cut) and removed. The primary steel beam no longer supporting any secondary beams will then be cut and removed. All beams will be temporarily supported during cutting/removing to avoid uncontrollable swinging or falling.

2.1.2.3 Phase II - Exterior Brick Wall Removal

Foster Wheeler will utilize a barge-mounted crane equipped with a 2,000 pound demolition ball to remove the brick wall from around and between the existing steel columns. The barge will move from the South end to the North end, carefully breaking the brick wall inward. The barge will be located adjacent to the side of the pier to catch any falling brick debris towards the water. The demolished brick wall will be removed from the floor slab manually on the second floor and by utilizing a bobcat skidsteer loader, or similar light equipment, on the first floor. Loose brick will be moved to the staging area on the landward part of the site.

2.1.2.4 Phase III - Building Removal

With the brick facing removed and cleaned up, the concrete roof and second story floor removal will be the next step in the process. The concrete roof and second story floor will be supported from beneath with scaffolding/shoring. The roof and second story floor sections will be measured and calculated for weight to insure a safe load for the barge mounted crane. A lift permit will be issued for a crane to operate from the barge to lift each section of concrete. Once supported, the roof and floor will be saw cut into sections. Drilled-in anchor bolts will be embedded into the slab for rigging points. A four-point pick with a four-part cable system will be used for the lift. These sections will then be lifted by the crane staged on the barge and temporarily staged on the barge for later relocation to a designated storage area on the island.

Foster Wheeler will start the remainder of the demolition from the southern end of the building. The pier begins at the south end of the building; therefore, Foster Wheeler will perform select demolition work from the land within reach of the excavator (*i.e.,* approximately 40 feet). The remainder of the work will be performed from barges located on the east and west sides of the building. Working from barges, Foster Wheeler will advance the demolition of the building towards the north, one section (18ft. long by 42ft. wide) at a time. Foster Wheeler will utilize hydraulic excavators, equipped with shear attachments, on the barges and additional small construction equipment (*e.g.,* Bobcat rubber tire skidsteer loader) to transport the debris to the appropriate staging area.

The concrete encasement around the secondary beams (north-south) will be removed from the connection points to the primary beams with a ramhoe. The secondary beams will then be cut (hydraulic shears) and removed from the primary beams. Then the concrete encasement around the primary beams (east-west) will be chipped away from the connection points to the steel columns. The primary beams will then be cut (hydraulic shears) and removed from the columns. Each beam will be supported by the hydraulic excavators as it is being cut from its support. For the two-story portion of the building, this process will be performed for the second story supporting steel, and then repeated for the first story supporting steel.

At this point, the outside line of columns, which are not supporting any steel, will be cut off as close to the concrete base as possible.

Care will be taken to prevent beams, columns and debris from dropping any distance that could damage the concrete slab. Timber matting or steel plates may be utilized as necessary to prevent puncturing of the concrete slab allowing debris to fall into the water.

Foster Wheeler will remove and process all debris associated with each section prior to continuing further demolition in order to maintain a safe work area, free of debris and eliminate the need for additional time to separate brick/concrete debris from steel debris. This entire process will be continued until the entire structure is removed and all debris has been processed accordingly.

2.1.2.5 Building Restoration

This section pertains to the building restoration that will take place once the portion to be demolished has been completed. Foster Wheeler has installed the concrete block wall on the second story of the portion of Building 35 to remain. Also, at this time, Foster Wheeler is scheduling the jib crane power to be disconnected and reinstalled within the existing concrete floor slab. Foster Wheeler will saw-cut a small trench in the slab to accept the conduit for the crane power source. Foster Wheeler will then place a concrete cap over the conduit for protection, finished to the existing floor elevation.

Foster Wheeler will also remove and reinstall the existing light standard in an area adjacent to the jib crane.

Lastly, Foster Wheeler will address final building restoration items including the southern building face, roof termination, fascia system and roof tie in details with the Navy next year prior to demolition activities being completed.

ATTACHMENT A

SITE MAP AND HISTORIC DRAWINGS

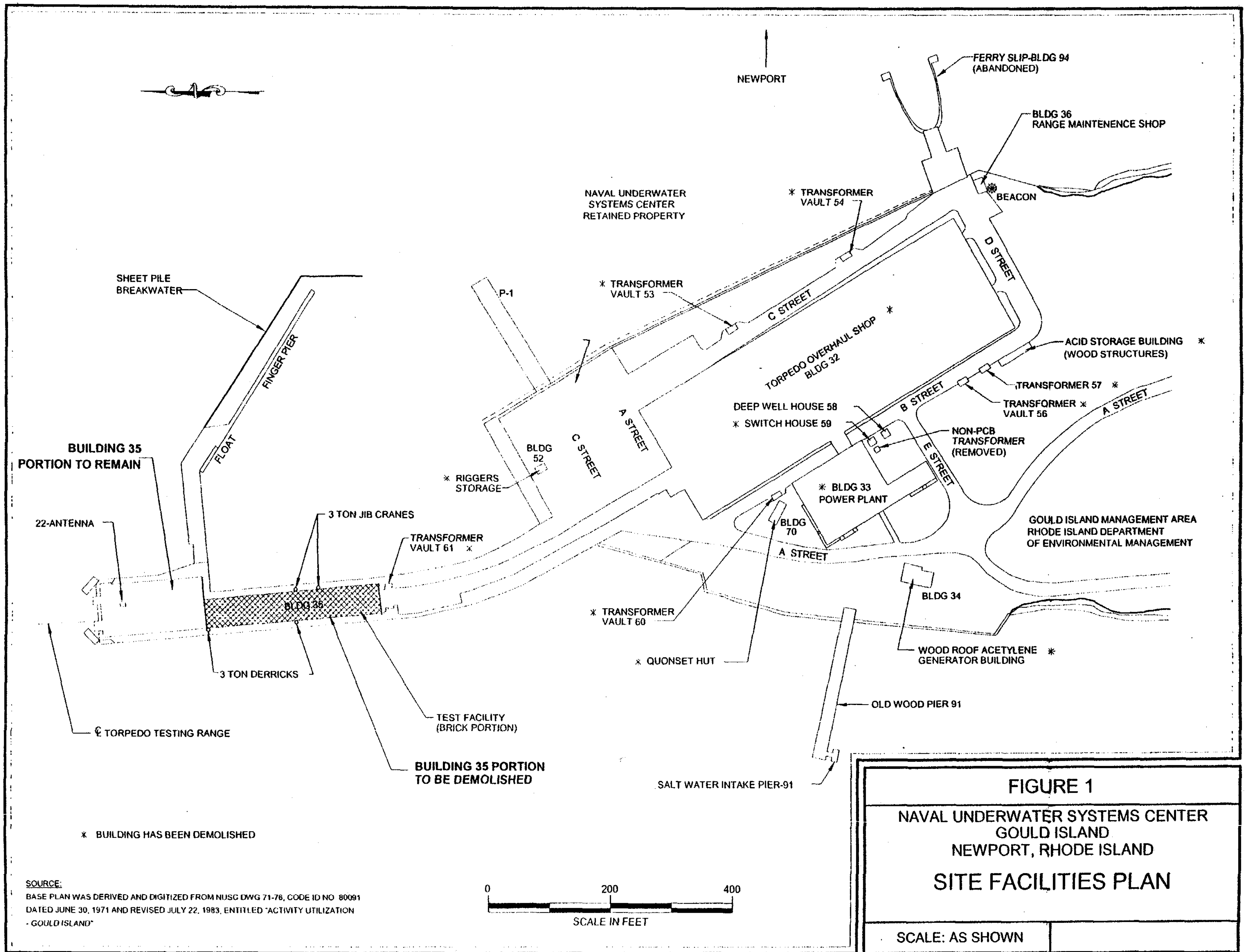


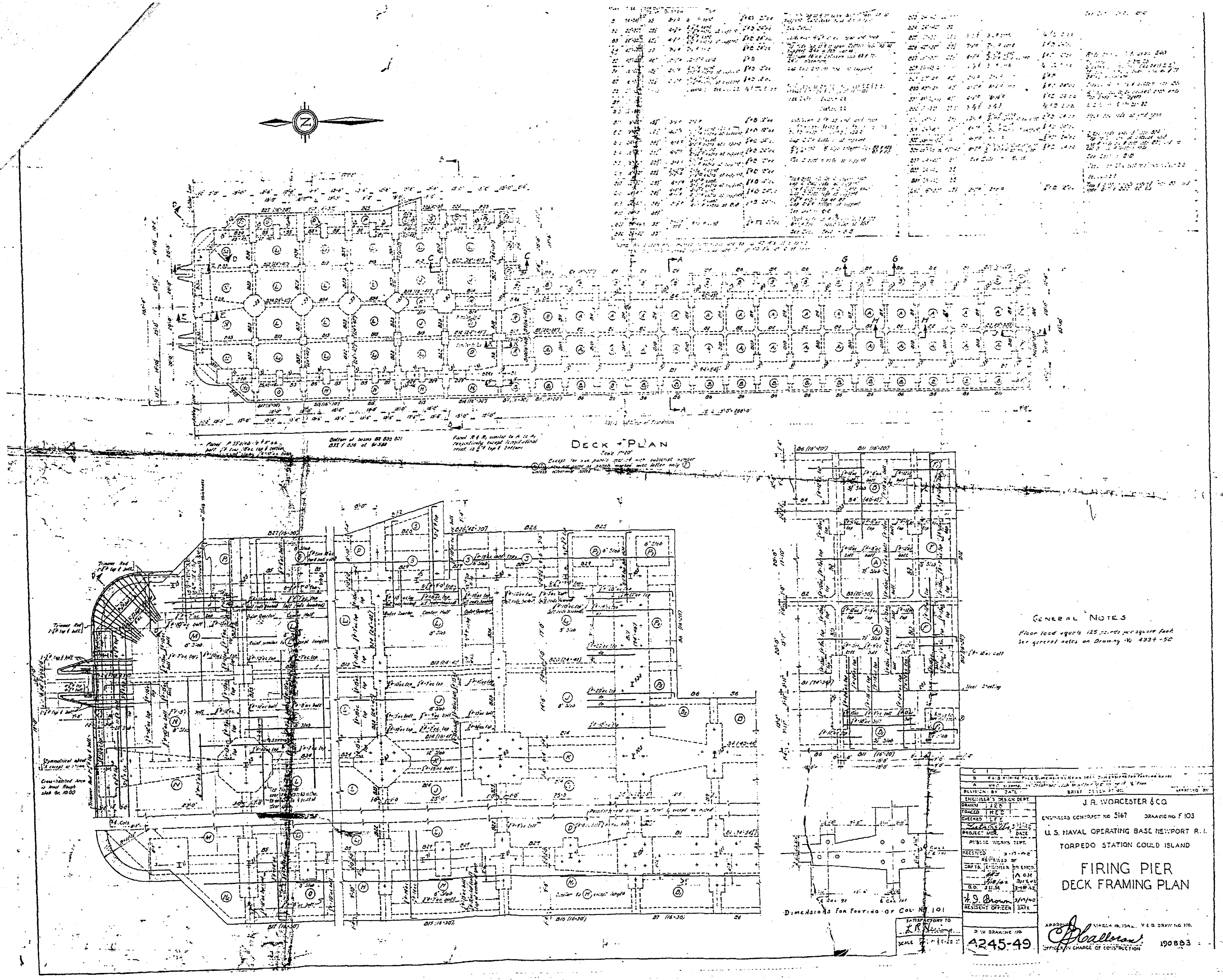
FIGURE 1

NAVAL UNDERWATER SYSTEMS CENTER
GOULD ISLAND
NEWPORT, RHODE ISLAND

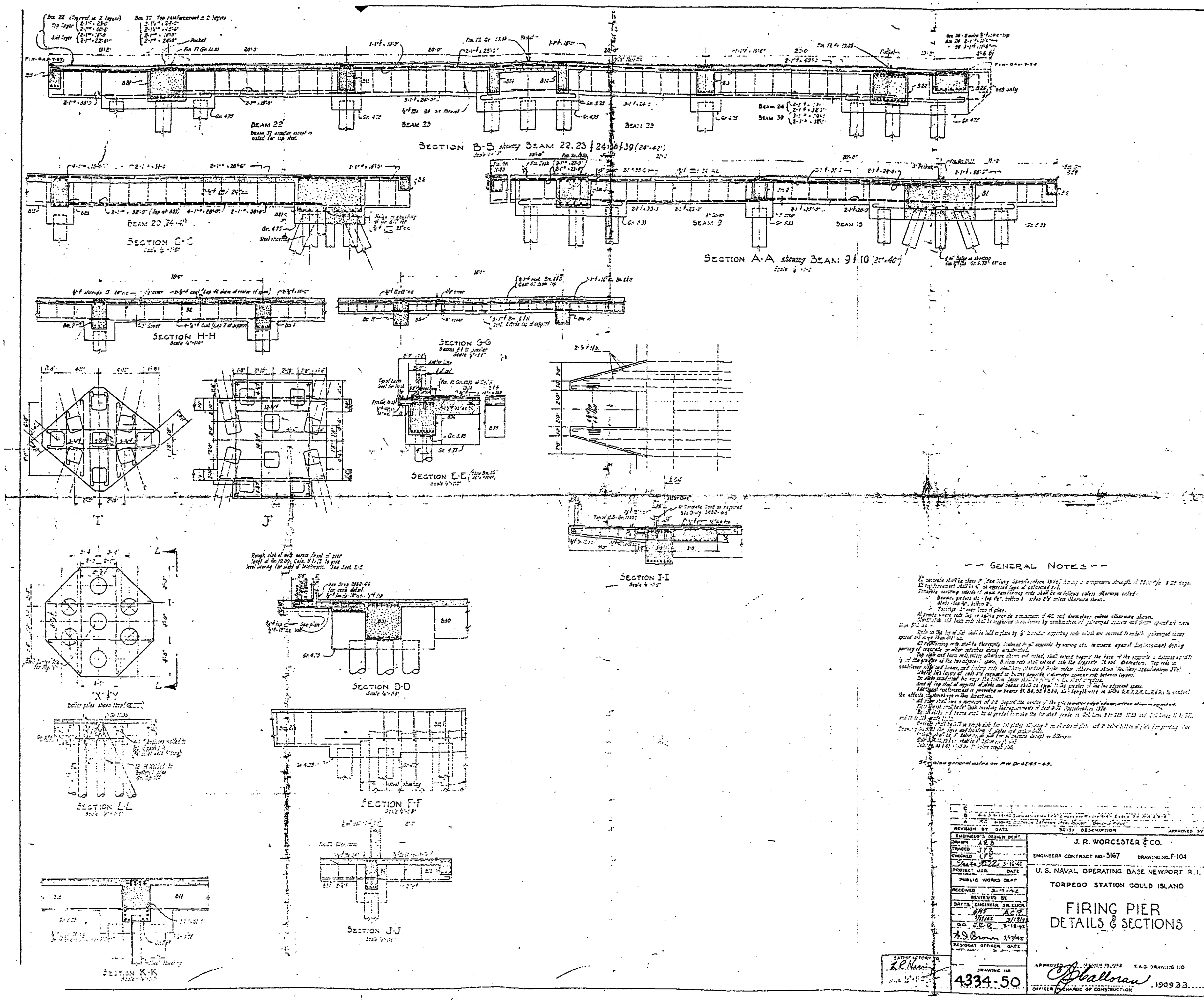
SITE FACILITIES PLAN

SCALE: AS SHOWN

CADDFILE: GOULD002.DWG


DECK PLAN
GENERAL NOTES
Floor load equals 125 pounds per square foot.
See general notes on Drawing No. 4934-50
Dimensions For Footing of Col. No. 101
J. R. WORCESTER & CO.
ENGINEERS CONTRACT NO. 5167
DRAWING NO. F 103
U. S. NAVAL OPERATING BASE NEWPORT R. I.
TORPEDO STATION GOULD ISLAND
FIRING PIER
DECK FRAMING PLAN
P. W. DRAWING NO.
4245-49
OFFICER IN CHARGE OF CONSTRUCTION
Y & D. DRAWING NO.
190883

00057IBIZ



SECTION B-B showing BEAM 22, 23, 24 & 39 (24"-42")
BEAM 22
BEAM 23
SECTION C-C
BEAM 20 (24"-41")
SECTION A-A showing BEAM 9 & 10 (27"-40")
BEAM 9
BEAM 10
SECTION H-H
SECTION G-G
SECTION E-E
"I"
"J"
"X" & "Y"
SECTION I-I
SECTION D-D
SECTION L-L
SECTION F-F
SECTION J-J
SECTION K-K
GENERAL NOTES
J. R. WORCESTER & CO.
ENGINEERS CONTRACT NO. 5167
DRAWING NO. F-104
U. S. NAVAL OPERATING BASE NEWPORT R.I.
TORPEDO STATION GOULD ISLAND
FIRING PIER
DETAILS & SECTIONS
REVISION BY DATE
BRIEF DESCRIPTION
APPROVED BY
ENGINEER'S DESIGN DEPT.
DRAWN
TRACED
CHECKED
PROJECT MGR. DATE
PUBLIC WORKS DEPT.
RECEIVED 3-19-42
REVIEWED BY
DRFTS. ENGINEER
RESIDENT OFFICER DATE
SATISFACTORY TO
DRAWING NO.
4334-50
APPROVED MARCH 19, 1942
Y. & D. DRAWING NO.
OFFICER IN CHARGE OF CONSTRUCTION
190933

ATTACHMENT B

ENGINEERING CALCULATIONS

FOSTER WHEELER ENVIRONMENTAL CORPORATION

BY J. LYON DATE 9/29/00 SHEET 1 OF 4

CHKD. BY [illegible] DATE 9/29/00 OFS NO. 1284.0044.9901 DEPT. NO. CE

CLIENT NAVAL FACILITIES ENGINEERING COMMAND - NORTHERN DIVISION

PROJECT GOULD ISLAND BUILDING DEMOLITION

SUBJECT BLDG. 35 STRUCTURAL ANALYSIS

PROBLEM: DETERMINE CAPACITY OF BUILDING TO SUPPORT A HYDRAULIC EXCAVATOR (KOMATSU PC-300) WORKING FROM BUILDING SLAB.

DRAWING P.W. 4245-49 AND P.W. 4334-50

1. CAPACITY OF SLAB BASED ON f'_c, A_s AND f_s (ALTERNATE DESIGN METHOD)

SLAB A1 (DWG. 4245-49) $h = 7.5''$ $d = 7.5'' - 2''(\text{cover}) = 5.5''$

ASSUME 12" STRIP ∴ $b = 12''$

$f'_c = 3500$ psi $f_s = 18$ ksi $f_c = 0.45 f'_c = 0.45(3500)$

REINFORCEMENT: TOP = #4@8" BOTT. #4@9" $f_c = 1575$ psi

$$n = \frac{E_s}{E_c} = \frac{2.9\times10^7}{57000\sqrt{f'_c}} = 8.6 \quad \text{USE } 8.5$$

CALCULATE +M A_s (BOTT #4@9") = 0.27 in² $\rho = \frac{A_s}{bd} = \frac{0.27}{12(5.5)} = 0.0041$

$M_s = A_s f_s jd$ $j = 1 - \frac{k}{3}$ $\rho n = 0.035$

$$k = \sqrt{(2\rho n) + (\rho n)^2} - (\rho n) = \sqrt{2(0.035) + 0.035^2} - 0.035$$

$k = 0.232$ ∴ $j = 1 - \frac{0.232}{3} = 0.923$

$$M_s = 0.27(18000)(0.923)\left(\frac{5.5}{12}\right) = 2{,}055\ \#\text{-}1$$

$$M_c = \tfrac{1}{2} f_c k j b d^2 = 0.5(1575)(0.232)(0.923)(12)\frac{(5.5)^2}{12} = 5{,}101\ \#\text{-}1$$ ∴ M_s governs

CALCULATE −M A_s (TOP #4@8") = 0.30 in² $d = 7.5 - 0.75(\text{cover}) = 6.75''$

$\rho = \frac{0.3}{12(6.75)} = 0.0037$ $\rho n = 0.032$ $k = 0.223$ $j = 0.926$

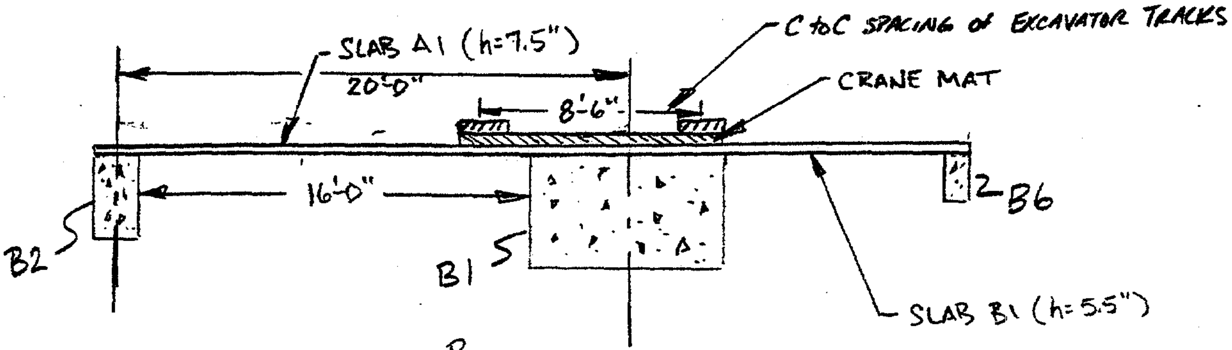
$$M_s = 0.3(18000)(0.926)\left(\frac{6.75}{12}\right) = 2{,}812\ \#\text{-}1$$

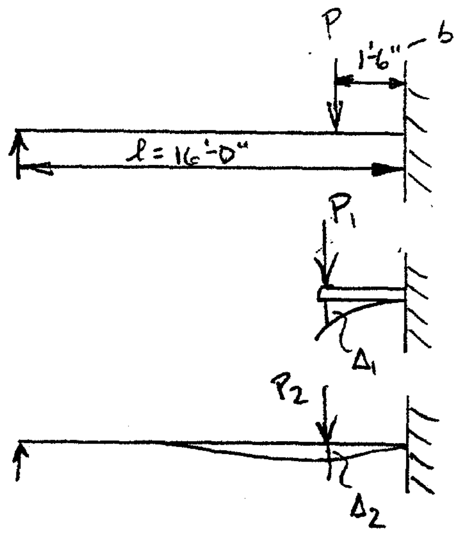
CONSIDERING DETERIORATION OF CONCRETE BY APPLYING A CAPACITY REDUCTION FACTOR OF 0.75 ∴ ALLOWABLE (+MOMENT) = 0.75 (2055) = 1541 #-1

(−MOMENT) = 0.75 (2812) = 2109 #-1

FWENC 581D 10/96

2. CHECK SLAB BASED ON FOLLOWING LOADING CONDITION
ASSUME KOMATSU PC-300, OPERATING WEIGHT = 80 kips
ASSUME PLACED ON WOODEN CRANE MATS





LOAD CONDITION, ASSUME 12" STRIP

$$P = \frac{80{,}000}{2(17)} = 2353^{\#}$$

(17) — TRACK LENGTH

WOODEN MAT DEFLECTION Δ_1

CONCRETE SLAB DEFLECTION Δ_2

CALCULATE DEFLECTIONS: $P = P_1 + P_2$ AND $\Delta_1 = \Delta_2$

PROPERTIES.

E_C - MODULUS OF ELASTICITY CONCRETE $= 57{,}000\sqrt{f'_c} = 3.37 \times 10^6$

I_C - MOMENT OF INERTIA CONCRETE $= \frac{bh^3}{12} = \frac{12(7.5)^3}{12} = 422 \text{ in}^4$

E_W - MOD. OF ELASTICITY WOOD (FROM CIVIL ENGINEER HANDBOOK) $= 1.2 \times 10^6$

I_W - MOMENT OF INERTIA WOOD $= \frac{bh^3}{12} = \frac{12(8)^3}{12} = 512 \text{ in}^4$

FOSTER WHEELER ENVIRONMENTAL CORPORATION

BY J. LYON DATE 9/29/00 SHEET 3 OF 4

CHKD. BY mGA DATE 9/29/00 OFS NO. 1284.0044.9901 DEPT. NO. CE

CLIENT NAVAL FACILITIES ENGINEERING COMMAND - NORTHERN DIVISION

PROJECT GOULD ISLAND BUILDING DEMOLITION

SUBJECT BLDG. 35 STRUCTURAL ANALYSIS

DEFLECTION CALCULATION (CONT.)

WOOD: Δ_1

$$\Delta_1 = \frac{P_1 b^3}{3 E_W I_W} = P_1 \left[\frac{(1.5)^3}{3(1.2 \times 10^6)(512)} \right] = \frac{P_1}{5.46 \times 10^8}$$

CONCRETE: Δ_2

$$\Delta_2 = \frac{P_2 a^2 b^3}{12 E_c I_c \ell^3} (3\ell - a) \quad \text{where } a = \ell - b = 16 - 1.5 = 14.5'$$

$$\Delta_2 = P_2 \left[\frac{14.5^2 (1.5)^3}{12(3.37 \times 10^6)(422)(16)^3} (48 + 14.5) \right] = \frac{P_2}{1.58 \times 10^9}$$

$\Delta_1 = \Delta_2 \qquad P = P_1 + P_2 \qquad P_1 = P - P_2$

$$\therefore \frac{P_1}{5.46 \times 10^8} = \frac{P_2}{1.58 \times 10^9} \qquad \therefore P_1 = P_2 \frac{5.46 \times 10^8}{1.58 \times 10^9} = 0.346 P_2$$

$$P = P_1 + P_2 = 0.346 P_2 + P_2$$

$$2.353^k = 1.346 P_2 \qquad P_2 = 1.75^k \qquad P_1 = 0.603^k$$

CALCULATE MOMENT
FOR CONCRETE

$$-M_{2\,(\text{fixed end})} = \frac{P_2 ab}{2\ell^2}(a + \ell) = \frac{1.75(14.5)(1.5)}{2(16)^2}(14.5 + 16) = 2.27^{k\cdot'}$$

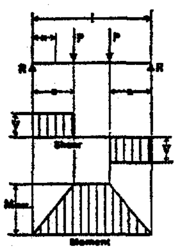
MOMENT FOR LOAD ONLY (WITHOUT SLAB DEAD LOAD) IS LARGER THAN ALLOWABLE MOMENT $2.27^{k\text{-}'} > 2.109^{k\text{-}'}$

$\therefore$ SLAB CAN NOT SUPPORT EXCAVATOR

STRUCTURAL — BEAM FORMULAS-2

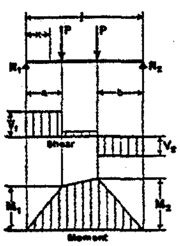
For nomenclature see page 8-01

9. SIMPLE BEAM—TWO EQUAL CONCENTRATED LOADS SYMMETRICALLY PLACED



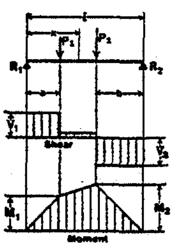
- Equivalent Tabular Load . . . . . . $= \frac{8Pa}{l}$
- $R = V$ . . . . $= P$
- M max. (between loads) . . . . . . $= Pa$
- M_x (when $x < a$) . . . . $= Px$
- $\Delta max.$ (at center) . . . . $= \frac{Pa}{24EI}(3l^2 - 4a^2)$
- Δx (when $x < a$) . . . . $= \frac{Px}{6EI}(3la - 3a^2 - x^2)$
- Δx (when $x > a$ and $< (l - a)$) . . $= \frac{Pa}{6EI}(3lx - 3x^2 - a^2)$

10. SIMPLE BEAM—TWO EQUAL CONCENTRATED LOADS UNSYMMETRICALLY PLACED



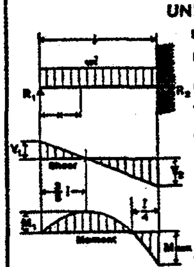
- $R_1 = V_1$ (max. when $a < b$) . . . . . $= \frac{P}{l}(l - a + b)$
- $R_2 = V_2$ (max. when $a > b$) . . . . . $= \frac{P}{l}(l - b + a)$
- V_x (when $x > a$ and $< (l - b)$) . . $= \frac{P}{l}(b - a)$
- M_1 (max. when $a > b$) . . . . . $= R_1 a$
- M_2 (max. when $a < b$) . . . . . $= R_2 b$
- M_x (when $x < a$) . . . . $= R_1 x$
- M_x (when $x > a$ and $< (l - b)$) . . $= R_1 x - P(x - a)$

11. SIMPLE BEAM—TWO UNEQUAL CONCENTRATED LOADS UNSYMMETRICALLY PLACED



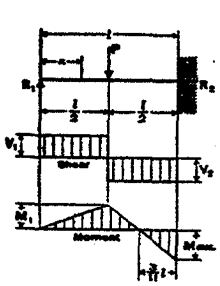
- $R_1 = V_1$ . . . . $= \frac{P_1(l - a) + P_2 b}{l}$
- $R_2 = V_2$ . . . . $= \frac{P_1 a + P_2(l - b)}{l}$
- V_x (when $x > a$ and $< (l - b)$) . . $= R_1 - P_1$
- M_1 (max. when $R_1 < P_1$) . . . . $= R_1 a$
- M_2 (max. when $R_2 < P_2$) . . . . $= R_2 b$
- M_x (when $x < a$) . . . . $= R_1 x$
- M_x (when $x > a$ and $< (l - b)$) . . $= R_1 x - P_1(x - a)$

12. BEAM FIXED AT ONE END, SUPPORTED AT OTHER—UNIFORMLY DISTRIBUTED LOAD



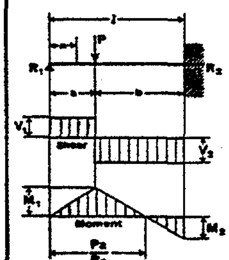
- Equivalent Tabular Load . . . . . . $= wl$
- $R_1 = V_1$ . . . . $= \frac{3wl}{8}$
- $R_2 = V_2$ max. . . . . $= \frac{5wl}{8}$
- V_x . . . . $= R_1 - wx$
- M max. . . . . $= \frac{wl^2}{8}$
- M_1 (at $x = \frac{3}{8}l$) . . . . $= \frac{9}{128}wl^2$
- M_x . . . . $= R_1 x - \frac{wx^2}{2}$
- $\Delta max.$ (at $x = \frac{l}{16}(1 + \sqrt{33}) = .4215l$) . $= \frac{wl^4}{185EI}$
- Δx . . . . $= \frac{wx}{48EI}(l^3 - 3lx^2 + 2x^3)$

13. BEAM FIXED AT ONE END, SUPPORTED AT OTHER—CONCENTRATED LOAD AT CENTER



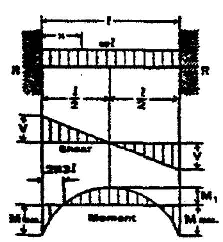
- Equivalent Tabular Load . . . . . $= \frac{3P}{2}$
- $R_1 = V_1$ . . . . $= \frac{5P}{16}$
- $R_2 = V_2$ max. . . . . $= \frac{11P}{16}$
- M max. (at fixed end) . . . . . . $= \frac{3Pl}{16}$
- M_1 (at point of load) . . . . . $= \frac{5Pl}{32}$
- M_x (when $x < \frac{l}{2}$) . . . . . . $= \frac{5Px}{16}$
- M_x (when $x > \frac{l}{2}$) . . . . . . $= P\left(\frac{l}{2} - \frac{11x}{16}\right)$
- $\Delta max.$ (at $x = l\sqrt{\frac{1}{5}} = .4472l$) . . $= \frac{Pl^3}{48EI\sqrt{5}} = .009317\frac{Pl^3}{EI}$
- Δx (at point of load) . . . . . $= \frac{7Pl^3}{768EI}$
- Δx (when $x < \frac{l}{2}$) . . . . . . $= \frac{Px}{96EI}(3l^2 - 5x^2)$
- Δx (when $x > \frac{l}{2}$) . . . . . . $= \frac{P}{96EI}(x - l)^2(11x - 2l)$

14. BEAM FIXED AT ONE END, SUPPORTED AT OTHER—CONCENTRATED LOAD AT ANY POINT



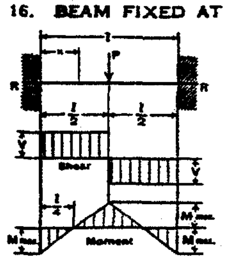
- $R_1 = V_1$ . . . . $= \frac{Pb^2}{2l^3}(a + 2l)$
- $R_2 = V_2$ . . . . $= \frac{Pa}{2l^3}(3l^2 - a^2)$
- M_1 (at point of load) . . . . $= R_1 a$
- M_2 (at fixed end) . . . . . . $= \frac{Pab}{2l^2}(a + l)$
- M_x (when $x < a$) . . . . . . $= R_1 x$
- M_x (when $x > a$) . . . . . . $= R_1 x - P(x - a)$
- $\Delta max.$ (when $a < .414l$ at $x = l\frac{l^2 + a^2}{3l^2 - a^2}$) $= \frac{Pa}{3EI}\frac{(l^2 - a^2)^3}{(3l^2 - a^2)^2}$
- $\Delta max.$ (when $a > .414l$ at $x = l\sqrt{\frac{a}{2l + a}}$) $= \frac{Pab^2}{6EI}\sqrt{\frac{a}{2l + a}}$
- Δa (at point of load) . . . . $= \frac{Pa^2b^3}{12EIl^3}(3l + a)$
- Δx (when $x < a$) . . . . . . $= \frac{Pb^2x}{12EIl^3}(3al^2 - 2lx^2 - ax^2)$
- Δx (when $x > a$) . . . . . . $= \frac{Pa}{12EIl^3}(l - x)^2(3l^2x - a^2x - 2a^2l)$

15. BEAM FIXED AT BOTH ENDS—UNIFORMLY DISTRIBUTED LOADS



- Equivalent Tabular Load . . . . . $= \frac{2wl}{3}$
- $R = V$ . . . . $= \frac{wl}{2}$
- V_x . . . . $= w\left(\frac{l}{2} - x\right)$
- M max. (at ends) . . . . $= \frac{wl^2}{12}$
- M_1 (at center) . . . . $= \frac{wl^2}{24}$
- M_x . . . . $= \frac{w}{12}(6lx - l^2 - 6x^2)$
- $\Delta max.$ (at center) . . . . . . $= \frac{wl^4}{384EI}$
- Δx . . . . $= \frac{wx^2}{24EI}(l - x)^2$

16. BEAM FIXED AT BOTH ENDS—CONCENTRATED LOAD AT CENTER



- Equivalent Tabular Load . . . . . $= P$
- $R = V$ . . . . $= \frac{P}{2}$
- M max. (at center and ends) . . . $= \frac{Pl}{8}$
- M_x (when $x < \frac{l}{2}$) . . . . . $= \frac{P}{8}(4x - l)$
- $\Delta max.$ (at center) . . . . . $= \frac{Pl^3}{192EI}$
- Δx . . . . $= \frac{Px^2}{48EI}(3l - 4x)$

From A.I.S.C. Steel Construction Manual - 1950.